

WG2 Summary



Conveners: **R. Ball, M. Sakuda, S. Zeller**

NuFact05 Workshop

June 25, 2005

Neutrino Scattering Physics

1. Experimental Results (**Zeller**)

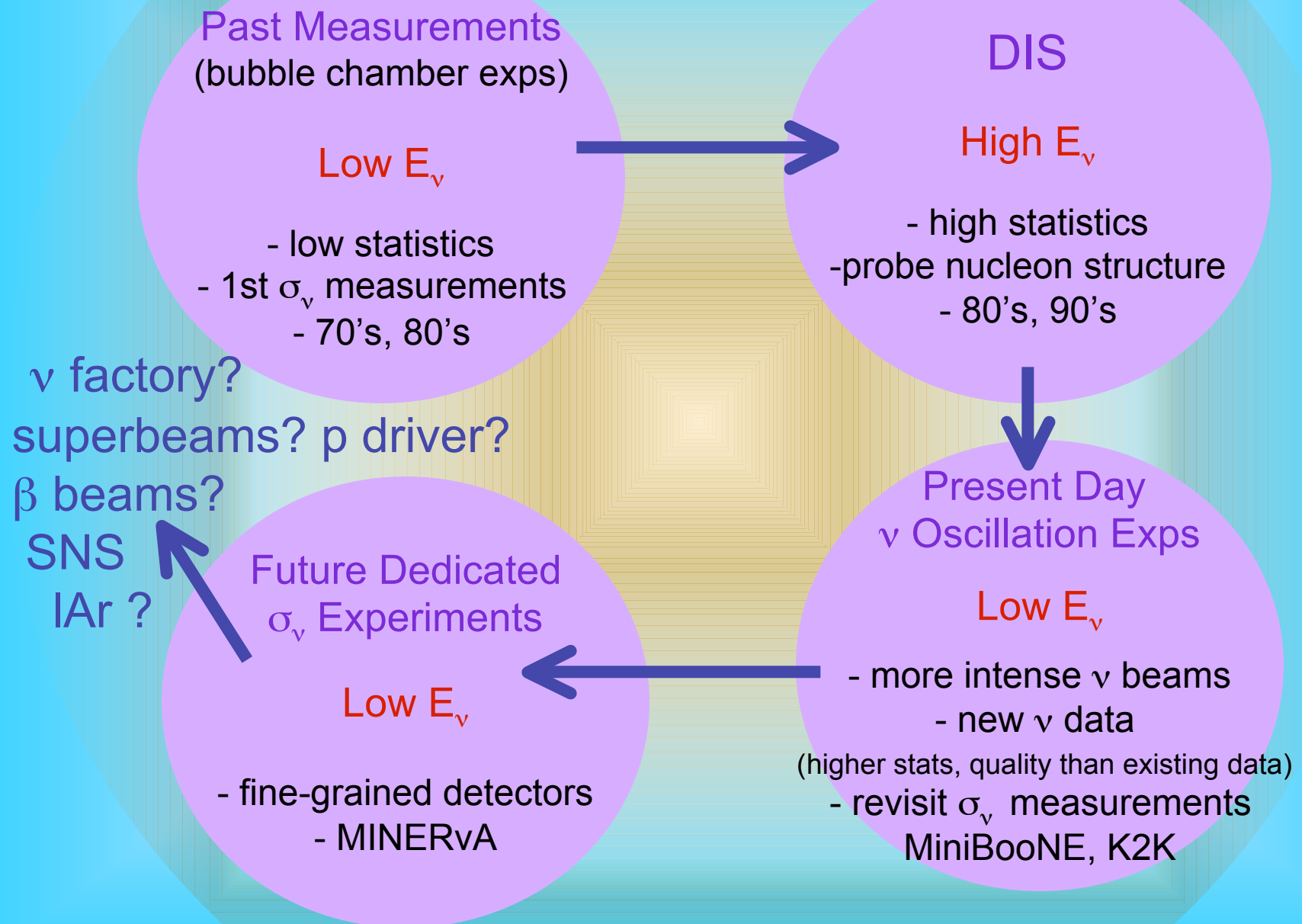
- achievements & plans

2. Theoretical Results (**Sakuda**)

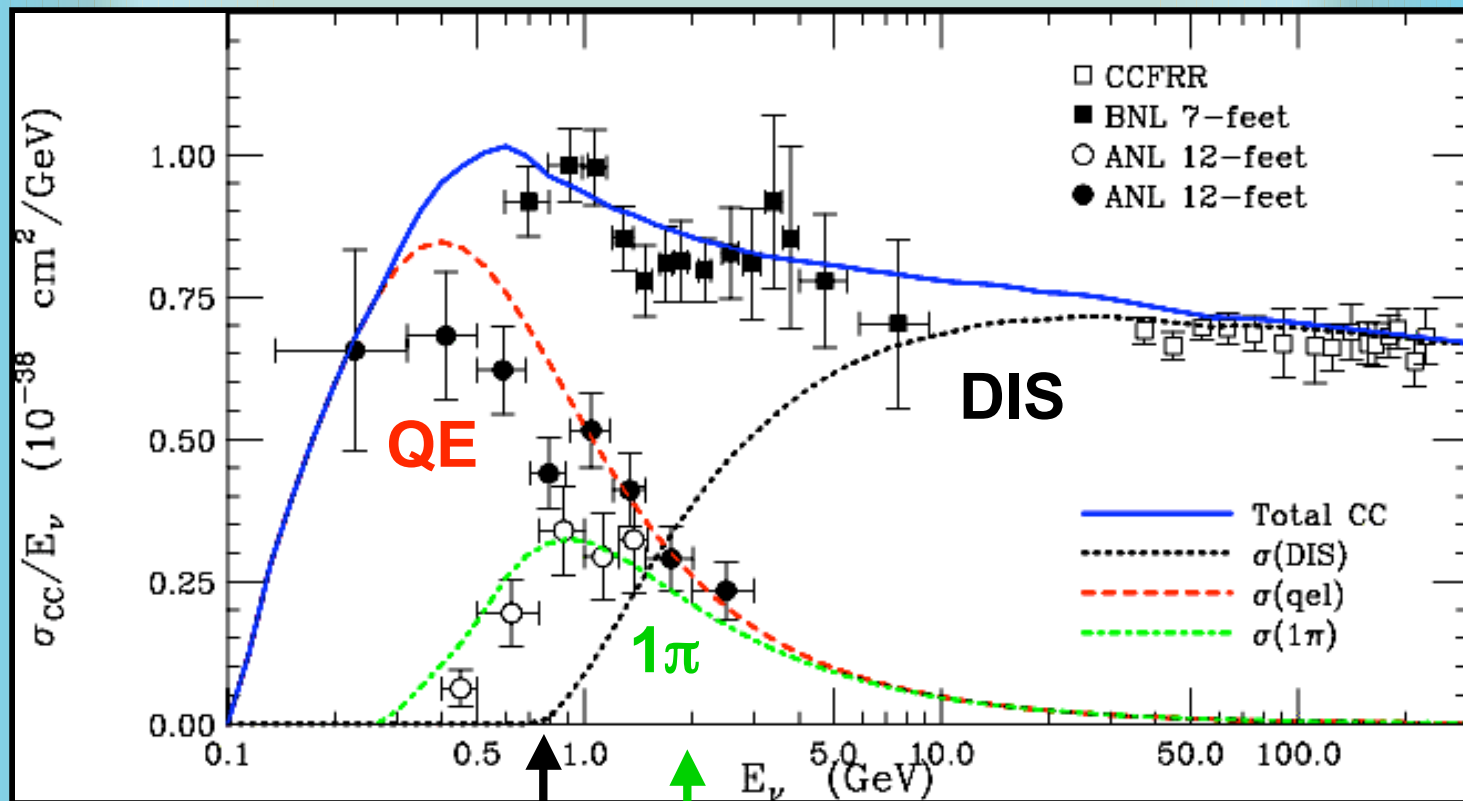
- achievements & plans



Where We Are Headed



Low Energy Neutrino Scattering



MiniBooNE, T2K

K2K, NOvA

MINOS, MINERvA

Super-K atmospheric ν

event samples observed
at these experiments
are a mixture

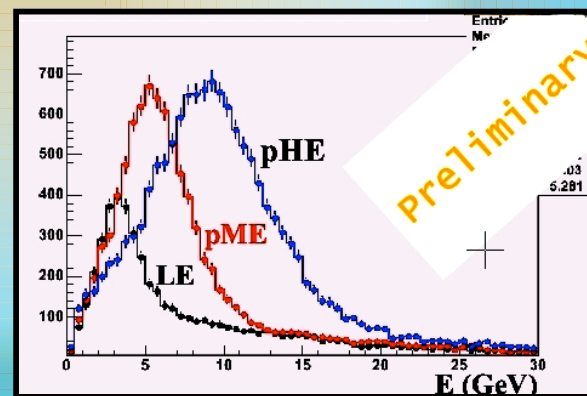
Why Low Energy σ_ν Measurements are Important

- **imperative for future osc exps: need to precisely predict both signal & background rates**
 - QE necessary to accurately predict signal rates in osc exps
 - need to know NC π^0 backgrounds for $\nu_\mu \rightarrow \nu_e$
 - need to know CC π^+ backgrounds for ν_μ disappearance
 - $\bar{\nu}$ cross sections for CP violation searches
- **interesting in their own right**
- **combination has increased effort towards obtaining more precise low energy σ_ν measurements ...**

WG2 ν Scattering: Status of Current Measurements

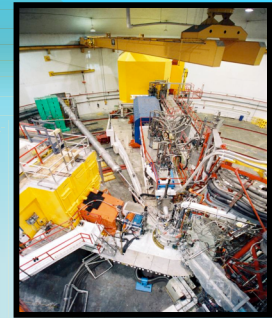
- **electron scattering at JLAB** (A. Bodek)
- **K2K** (L. Ludovici, M. Sakuda, F. Sanchez)
- **MiniBooNE** (I. Stancu, J. Monroe, M. Wascko)
- **MINOS** (A. Marchionni)
 - ν beam commissioned in Jan 2005
 - first beam events in near/far detectors
 - look forward to future ν scattering results from MINOS near detector

in all cases
new results
shown here
at NuFact!

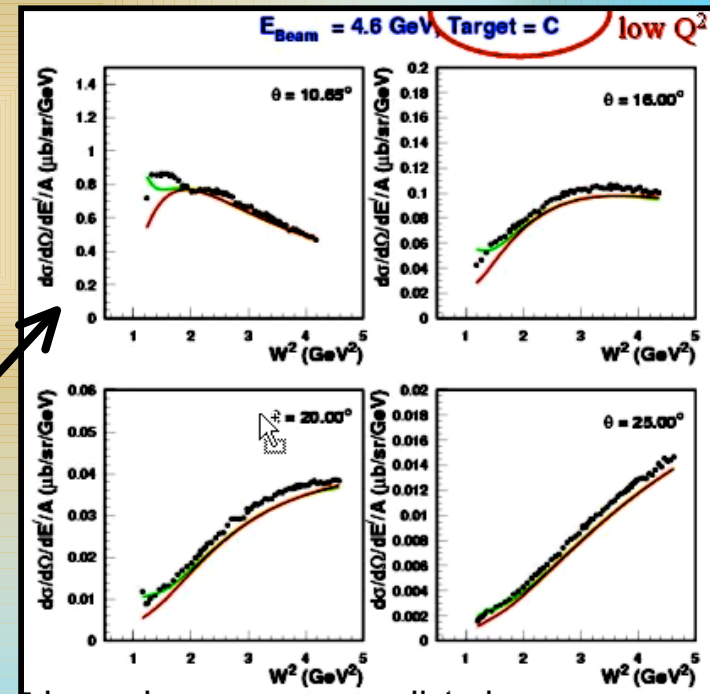


New Electron Data from JLAB

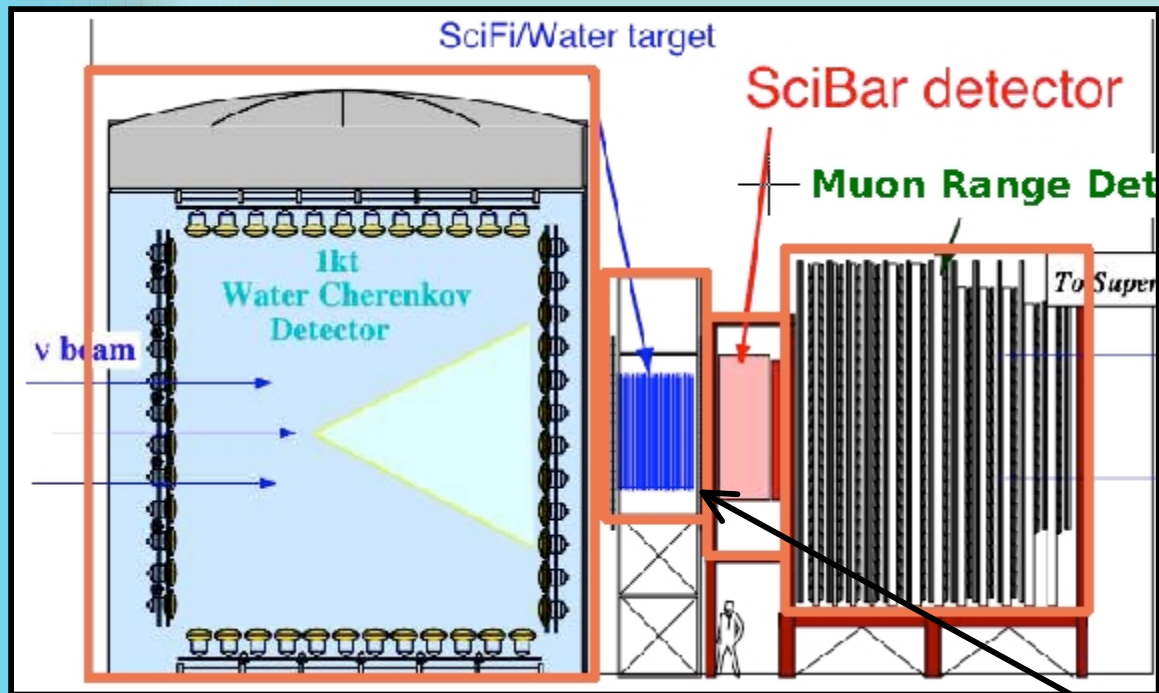
JUPITER e-A (A. Bodek)



- ν osc exps use nuclear targets (need accurate nuclear models; rely on higher statistics e-A measurements)
- collaborative program linking e^- and ν communities
- took data in January 2005
(1st look at this very preliminary data here at NuFact!)
- dedicated low Q^2 electron meas for ν community
- goal: fast track 5% σ measurements
(supply an important cross-check of σ_ν models)



Results From K2K



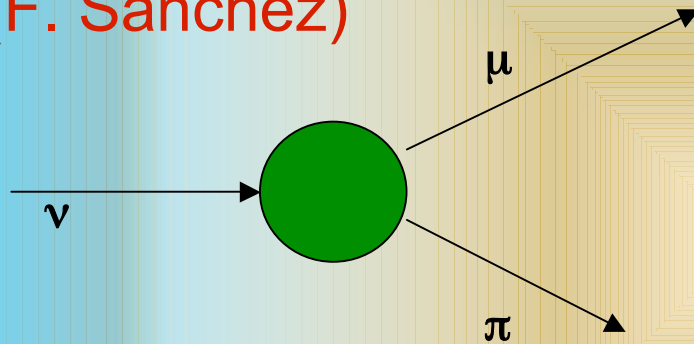
- new results on coherent charged pion production (F. Sanchez)

- M_A from QE event sample (M. Sakuda)

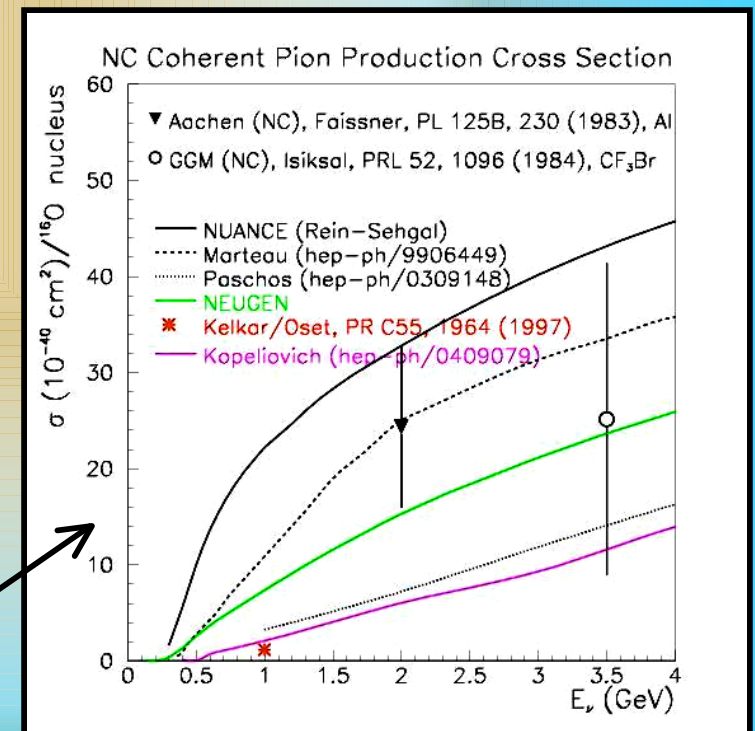
from fine grained
K2K near detectors

K2K Coherent π Production

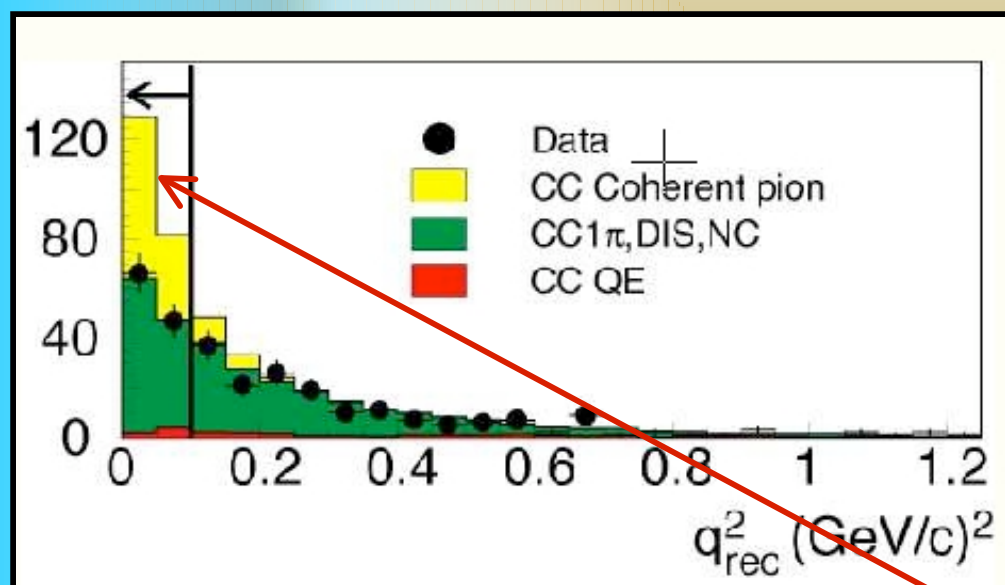
- “search for coherent charged pion production in neutrino-carbon interactions” ([hep-ex/0506008](#), submitted to PRL)
(F. Sanchez)



- neutrino coherently scatters off nucleus
 - negligible E transferred to target
 - distinct: low Q^2 , very forward π (compared to resonantly prod π 's)
- model predictions for this process vary widely ($\times 10$)



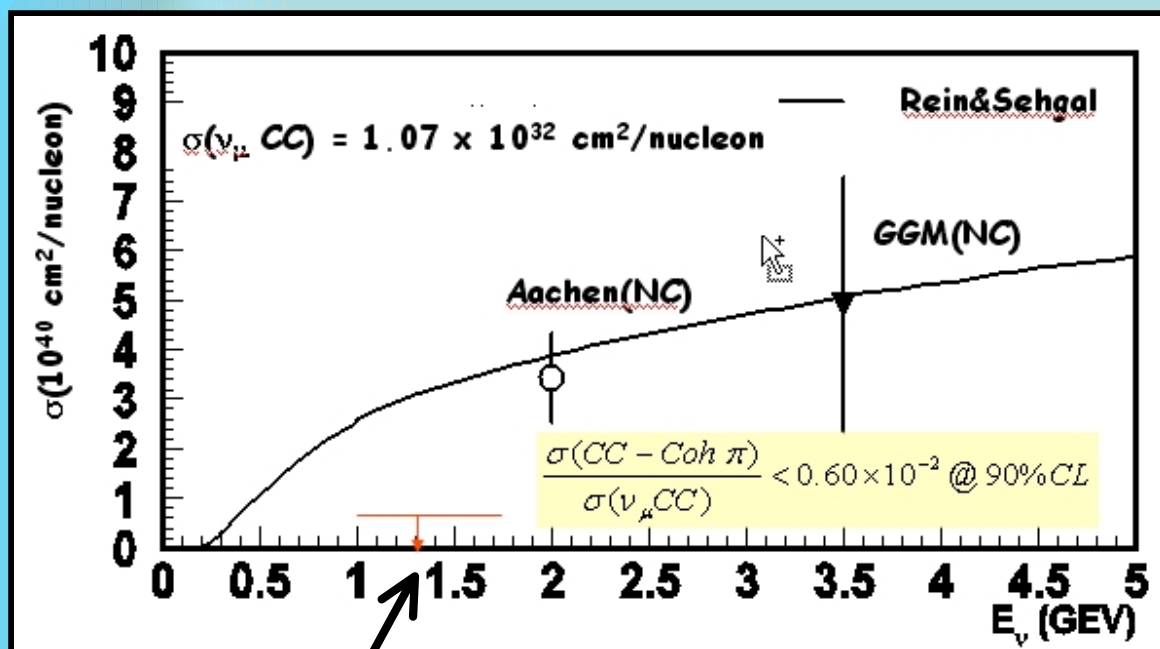
New K2K Coherent π^+ Results



(F. Sanchez)

- select an enriched coherent π sample by selecting events w/ low vertex activity (expect small nuclear recoil)
- low Q^2 is region where expect coherent π production
- report no evidence for coherent π production from K2K data

New K2K Coherent π^+ Results

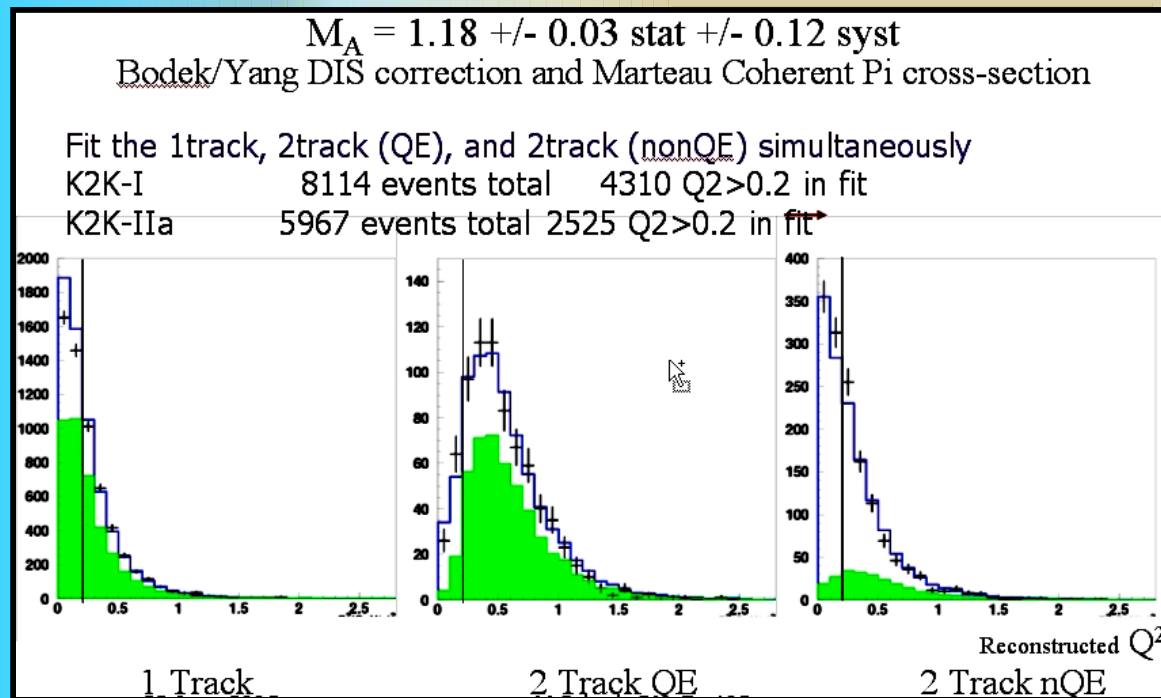


(F. Sanchez)

- based on this, set a limit (1.3 GeV, coherent is $< 0.6\%$ of v_μ CC σ)
- this is the 1st coherent π prod measurement below 2 GeV;
much interest & lively discussion in WG2
- will be interesting to compare to anticipated meas from MiniBooNE

K2K M_A from QE $\nu_\mu n \rightarrow \mu^- p$

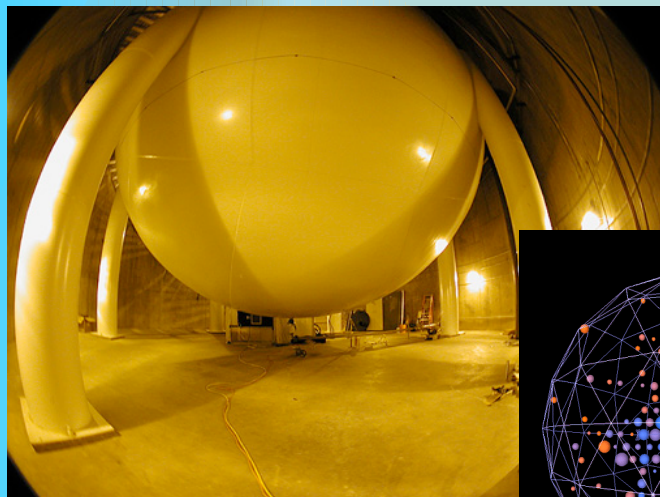
- extract axial vector mass, M_A , from QE data in SciFi detector (fundamental parameter in predicting shape, norm of QE σ)



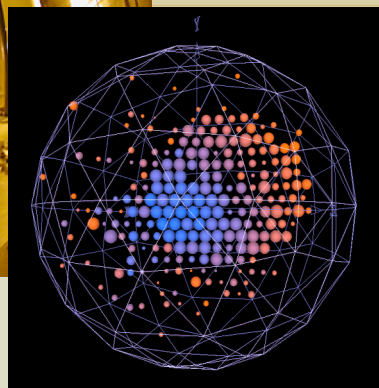
(M. Sakuda)

- effect on M_A from:
 - updated vector FF
 - new coherent π
- K2K is 1st meas of M_A on H_2O target
- part of important effort aimed at improving knowledge of M_A (and QE σ) on nuclear targets

New Results From MiniBooNE

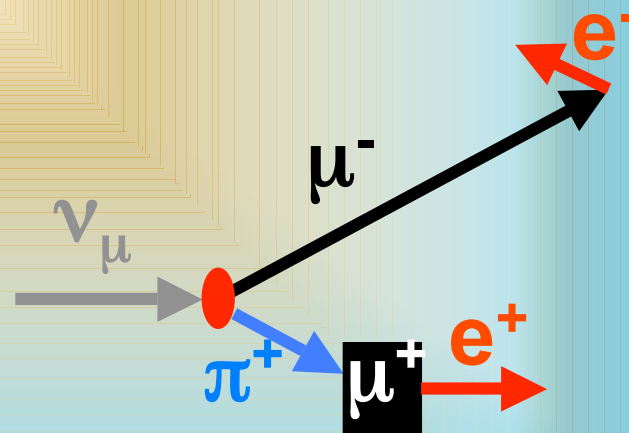


- new CC scattering results from MiniBooNE experiment (J. Monroe, M. Wascko)



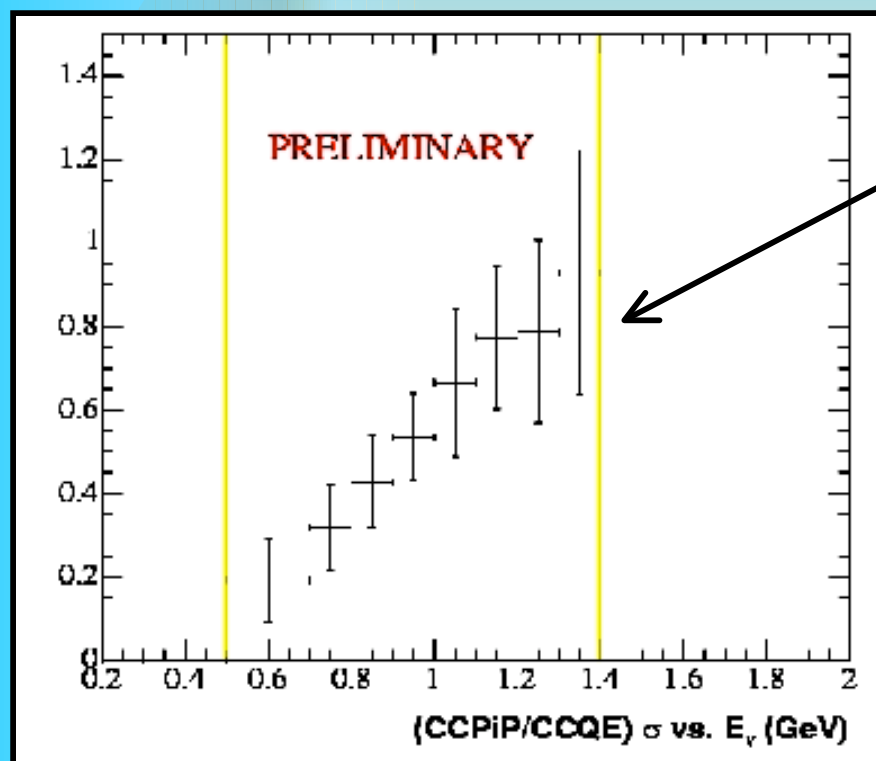
- Cerenkov detector
- high statistics samples of CC QE & CC $1\pi^+$ events

- high purity $\nu_\mu N \rightarrow \mu^- N \pi^+$ (CC $1\pi^+$) sample can be selected w/ simple requirement that events have 2 decay (Michel) electrons



- 5x more CC $1\pi^+$ data than all previous exps combined

MiniBooNE CC π^+ /QE

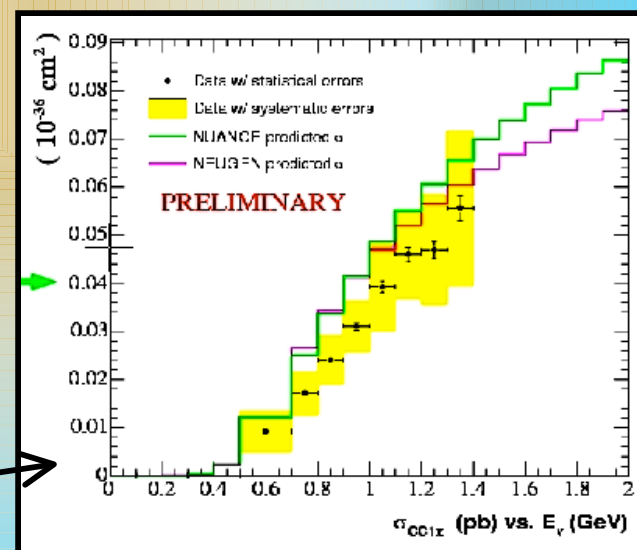


(J. Monroe)

- 1st look at ratio of CC $1\pi^+$ /QE cross sections as function of E_ν from MiniBooNE CC data

- provide important input for σ_ν simulations

- can also multiply ratio by QE σ prediction to extract CC π^+ cross section



(J. Monroe)

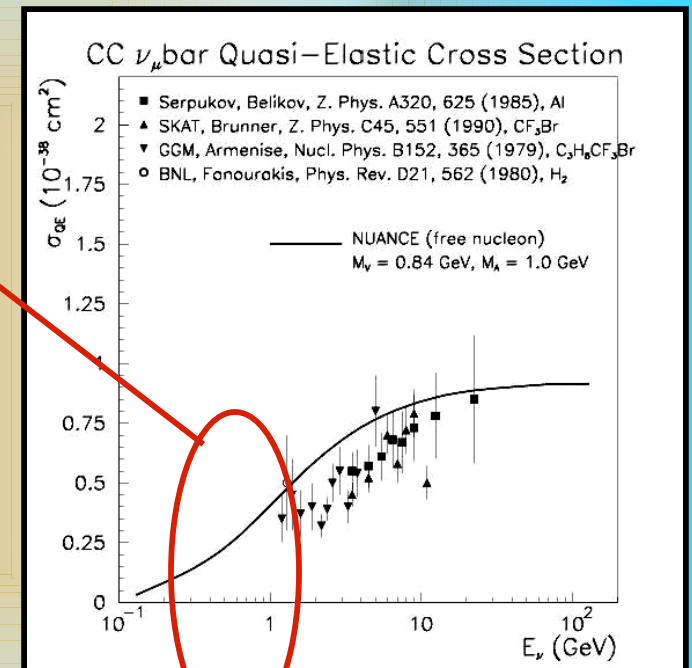
- first measurement at low E on nuclear target (CH_2)

WG2 ν Scattering: Future Initiatives

- MiniBooNE $\bar{\nu}$ running, SciBar (M. Wascko)
- MINERvA (J. Nelson)
- SNS (I. Stancu)
- β beams (C. Volpe)
- liquid Argon detection (B. Fleming, A. Meregaglia)

Future: MiniBooNE $\bar{\nu}$ Running

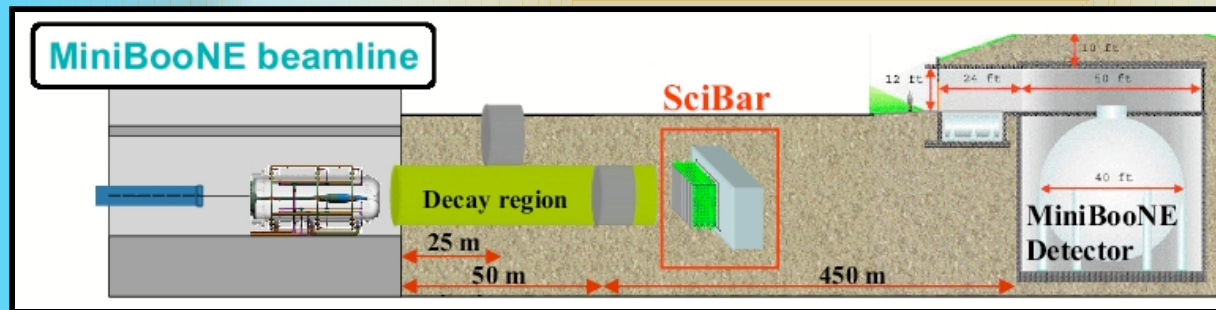
- antineutrino σ data less abundant
 - especially need low E measurements (where there is currently no data)
 - important for future ~~CP~~ searches
- $$P(\nu_\mu \rightarrow \nu_e) \neq P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$$
- MiniBooNE expects $\sim 10k$ $\bar{\nu}_\mu$ QE in 1 year (after cuts), $E_\nu \sim 0.8$ GeV
 - developed several new techniques for measuring ν contamination in $\bar{\nu}$ beam (“poor man’s sign selection”; no \vec{B} field)



(M. Wascko)

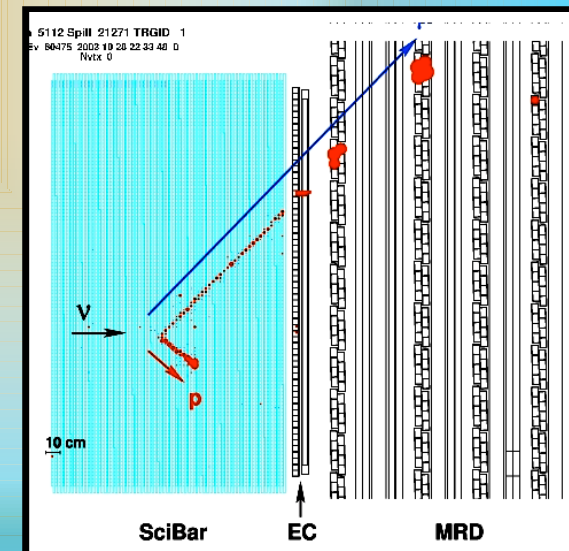
Future: Bringing K2K SciBar Detector to Booster ν Beamline

- window of opportunity to bring fine-grained K2K SciBar to BNB



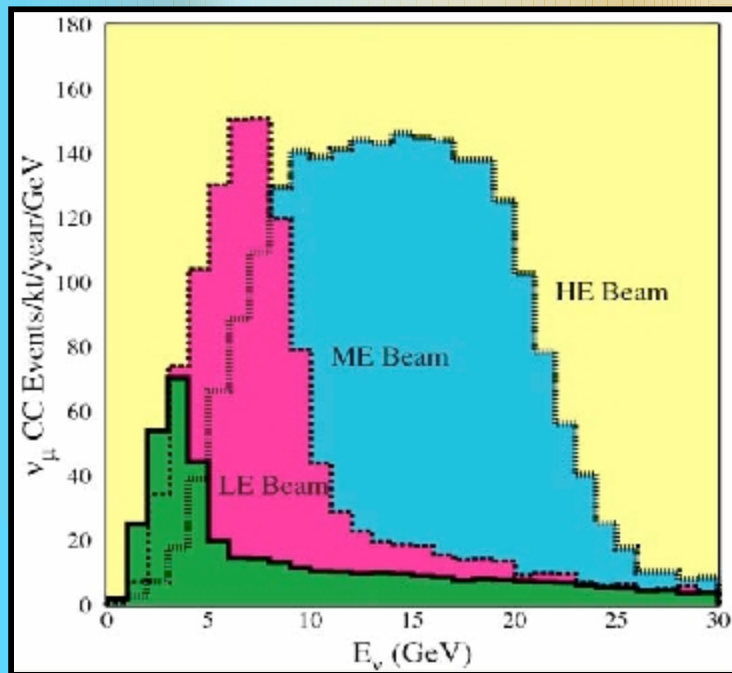
(M. Wascko)

- proposal recently submitted to Fermilab
 - measurements to aid MiniBooNE (in its capacity as near detector)
 - ν cross section measurements for T2K

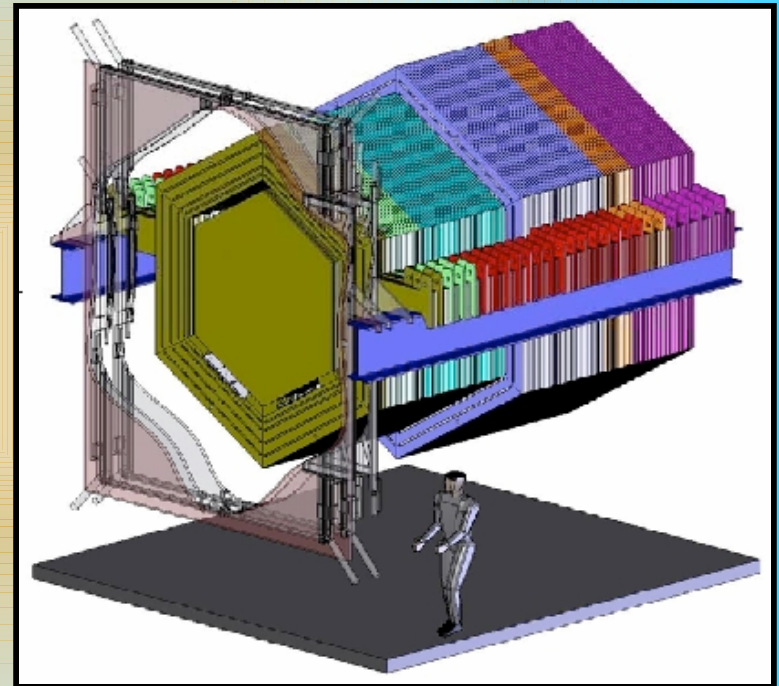


Future: MINERvA Experiment

- add'l near detector in NuMI beam line
- high statistics neutrino samples at a variety of beam energies (16×10^{20} POT in 4 years)



(J. Nelson)



- fully active, fine grained detector
- multiple nuclear targets (C,Fe,Pb)

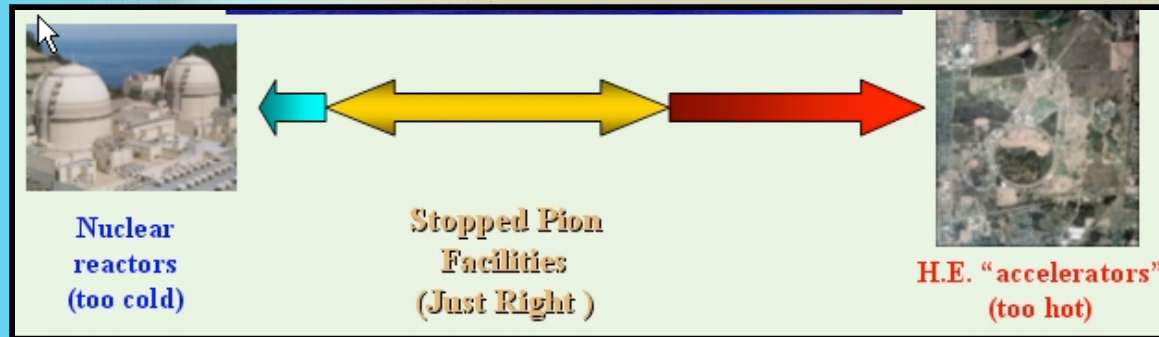
Future: MINERvA Experiment

- impressive laundry list of neutrino scattering measurements that can be studied with unprecedented detail ... (J. Nelson)

- Axial form factor of the nucleon
 - > Yet to be accurately measured over a wide Q^2 range.
 - Resonance production in both NC & CC neutrino interactions
 - > Statistically significant measurements with 1-5 GeV neutrinos *
 - > Study of “duality” with neutrinos
 - Coherent pion production
 - > Statistically significant measurements of σ or A-dependence
 - Nuclear effects
 - > Expect some significant differences for ν -A vs e/μ -A nuclear effects
 - Strange Particle Production
 - > Important backgrounds for proton decay
 - Parton distribution functions
 - > Measurement of high-x behavior of quarks
 - Generalized parton distributions
- construction in late 2006
 - commissioning end of 2008

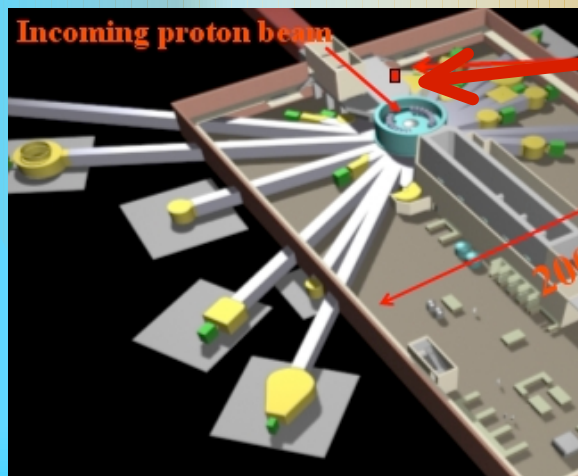
Future: Even Lower Energy (SNS)

- also effort to extend ν scattering activity down to even lower E's (5-50 MeV)
 - orders of magnitude lower than what we've been talking about



(I. Stancu)

- valuable for SN modeling and constraining nuclear models

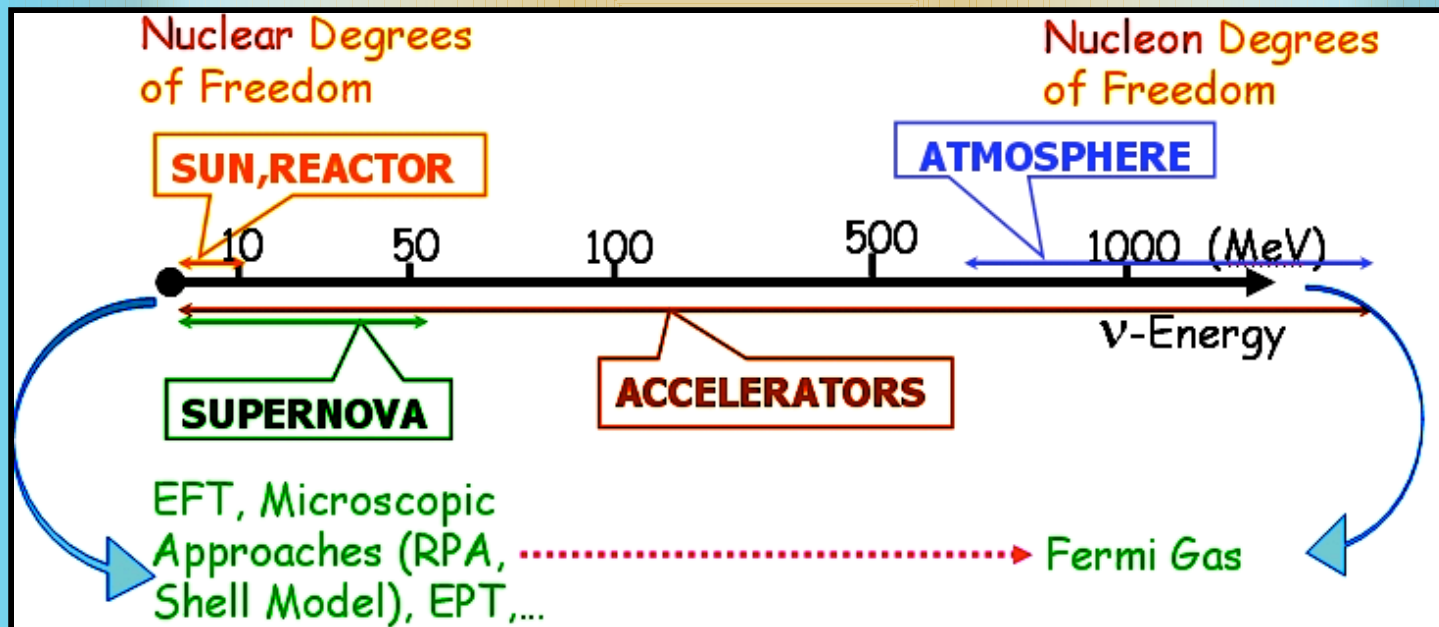
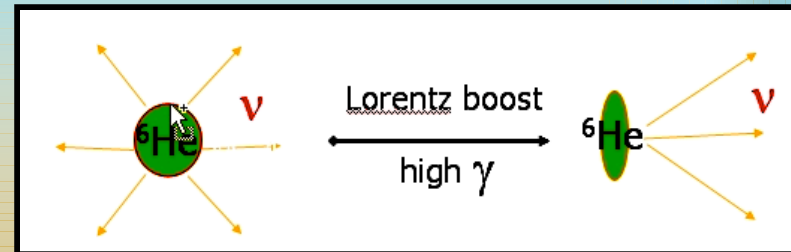


- build 20 ton neutrino detector at SNS (~1000 evts/yr)
- DAR well known ν spectra, separate ν flavors w/ timing cuts
- submitting proposal to DOE end of this month (start mid 2009)

Future: β Beams

- complementary to SNS:
possibility for low energy
beta beams (10 -100 MeV)

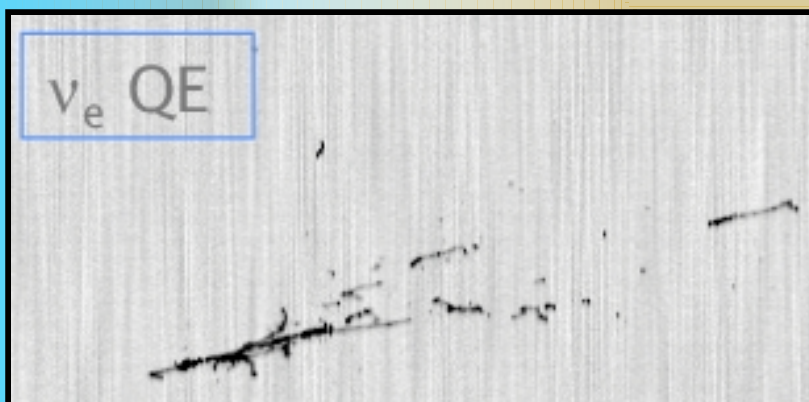
(C. Volpe)



- effort to span important gap between reactor and accelerator-based neutrino-nucleus interactions (where very few existing measurements)

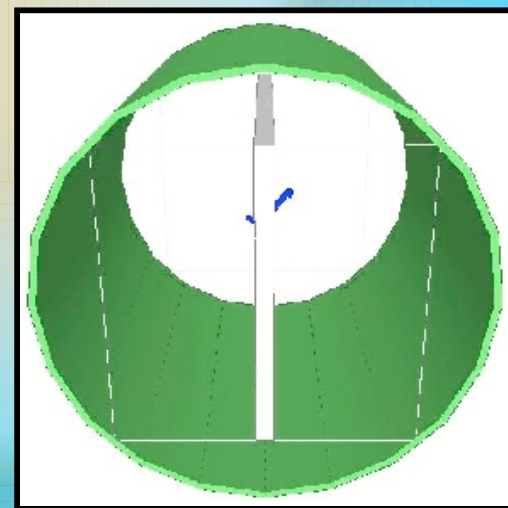
Future Detection: Liquid Argon

- potential for vast improvement in ν scattering measurements using extremely high resolution LAr detectors ...



- more precise σ_ν measurements; superior final state particle ID, improvements in neutron detection, + ν mag moment (B. Fleming)

- detailed studies of embedding inner water target (T2K, to aid in relating O and Ar measurements) (A. Meregaglia)




WG2 Achievements: Exp'l Meas

- K2K and MiniBooNE filling in gap in our knowledge of low energy neutrino scattering (and cross sections)
 - saw several new results this week
 - a lot of firsts (measurements in regions where previously no data)
- precise measurement of these σ 's, kinematic distributions will be an even more critical ingredient for future osc exps
- look forward further advancement w/ MINERvA in near future (and at even lower E's: SNS, β beams?)
- surveyed the landscape ... what's next after these exps?



WG2 Plans: What's Next? (questions for NuFact06)

- after K2K, MiniBooNE, MINERvA, what more will we need to know?
 - what other ν scattering measurements can & should be made that won't be covered by this menu?
 - what add'l info will be needed by future ν osc exps that we won't have in hand?
- 3 parts: beams, targets, detectors
J. Morfin plenary 

WG2 Plans: What's Next? (questions for NuFact06)

- **neutrino beams:**

- add'l $\bar{\nu}$ measurements? (post MiniBooNE)
- direct meas of (unosc) ν_e σ 's ($>$ reactor E)? (SNS, β beam)
- add'l dedicated hadron production exps? (post HARP, MIPP)
(for precise σ_ν , need precise knowledge of beam itself, do we have enough info?)
- narrow band beams for detailed NC studies

- **neutrino targets:**

- high stats light target measurements (H_2 , D_2)
- polarized targets?

- **improved detector technology:**

- next generation detectors? (lAr) + ??

Thank You!

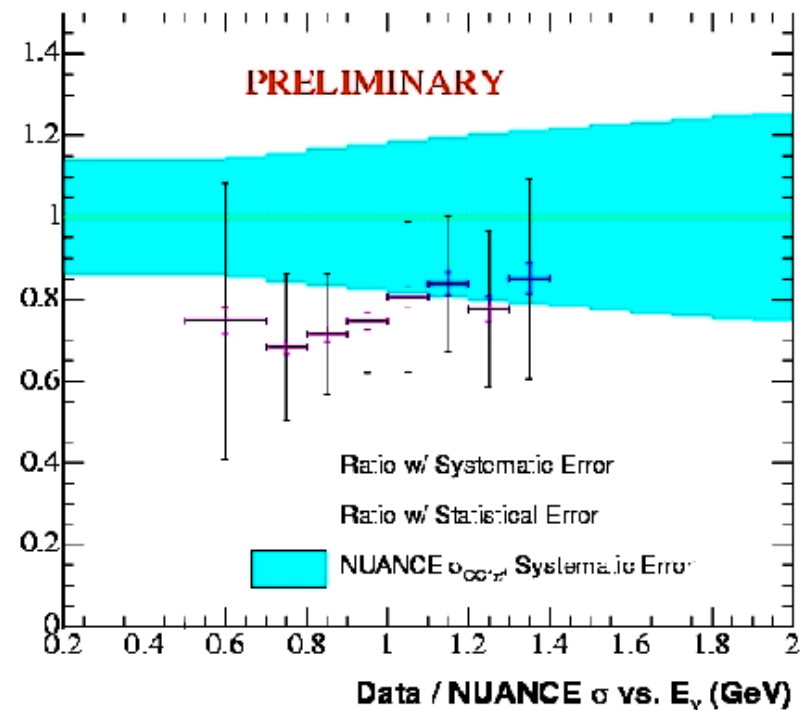
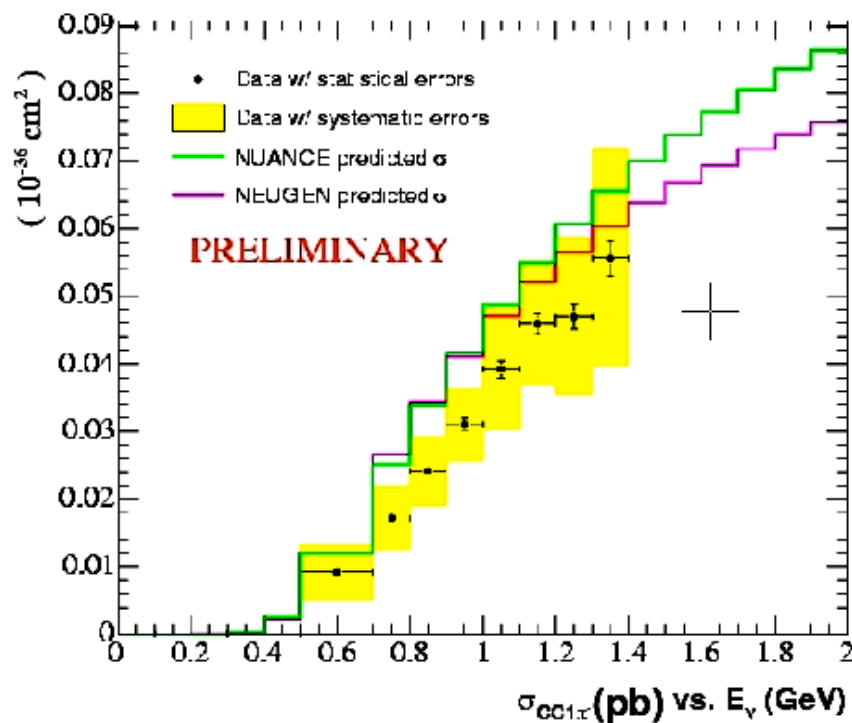
- would like to thank all of the WG2 speakers & participants
- would like to extend a sincere thank you to V. Palladino & INFN for the **very generous** travel support which made it possible for several WG2 speakers/participants to attend this workshop



Backup Slides

MiniBooNE CC π^+

- ratio to predicted $\sigma_{\text{NUANCE}}(\text{CCPiP})$ is $\sim 75\%$, but \sim within $\delta\sigma_{\text{NUANCE}}(\text{CCPiP})$



(J. Monroe)